

## FIELD OF THE INVENTION AND RELATED ART

In excimer lasers, a laser gas containing a noble gas and a halogen gas is sealingly stored in a

chamber, and the laser gas is once excited by ~~electric~~<sup>electrical</sup> discharging from an electrode, provided in the chamber, whereby laser light is produced. Also, in F<sub>2</sub> lasers, <sup>an</sup> F<sub>2</sub> gas is sealingly stored in a chamber, and  
5 the laser gas is once excited by ~~electric~~<sup>electrical</sup> discharging from an electrode, provided in the chamber, whereby laser light is produced.

SUMMARY OF THE INVENTION

10 In such excimer lasers or F<sub>2</sub> lasers, it is necessary to circulate the laser gas within the chamber in order to feed the laser gas to the electric discharging field of the electrode. To this end, within the chamber, there is circulating means for  
15 laser gas circulation such as a blowing machine (blower or circulating fan), for example. If the lifetime of the blowing machine provided in the chamber is short, the operation of the laser has to be stopped frequently for replacement of the laser or  
20 blowing machine or for repair of the same. In cases where the laser is used as a light source in an exposure apparatus, it largely affects the productivity of the apparatus. Since the blowing machine is disposed within the chamber, it takes <sup>a</sup>  
25 much time for replacement or repair of the same.

A factor that influences the lifetime of the blowing machine may be the lifetime of bearing means

for holding a rotational shaft of blowing fans of the blowing machine. Generally, the lifetime of <sup>each</sup> bearing means is shorter with a larger load applied in operation. Therefore, if the number of revolutions of

5 the blowing fans is enlarged to increase the blowing power of the blowing machine, with a result of enlargement of the load applied to the bearing means for supporting the rotational shaft, it accelerates wear and shortens the lifetime of the bearing.

10 Namely, if the blades of the blowing machine are rotated at a high speed for high frequency laser oscillation, the lifetime of the bearing means for supporting the blade rotational shaft of the blowing machine is shortened.

15               However, in an exposure apparatus having an excimer laser, for example, as an exposure light source, normally it is required that the excimer laser is oscillated at a high frequency for improved processing performance of the apparatus. Therefore,

20 it is not practical to use the blowing machine at its low blowing power level for prolongation of the lifetime of the bearing. On the other hand, for the reasons described above, if replacement or repair of the excimer laser or the blowing machine occurs

25 frequently, in an exposure apparatus having an excimer laser as an exposure light source, it leads to decreased productivity or throughput.

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Further, in gas laser devices, the lifetime of the blowing machine disposed in the chamber where the laser gas is stored should be longer than the lifetime of at least the chamber.

5           It is accordingly an object of the present invention to provide a gas laser device having a long lifetime and a high power.

          It is another object of the present invention to provide an exposure apparatus or a device  
10   manufacturing method ~~with use of~~ <sup>that</sup> such a gas laser device as an exposure light source, whereby high productivity is assured.

          In accordance with an aspect of the present invention, there is provided a gas laser device,  
15   comprising: a chamber for sealingly storing a laser gas therein; a discharging electrode for exciting the laser gas through ~~electric~~ <sup>electrical</sup> discharging, so that laser light is outputted from said chamber; circulating means for circulating the laser gas within said  
20   chamber so that the laser gas passing an electric discharging region of said discharging electrode is circulated in said chamber and is returned to said ~~electric~~ <sup>electrical</sup> discharging region of said discharging electrode; and control means for controlling said  
25   circulating means so that said circulating means provides different gas circulation capacities, being different for an in-operation state in which the laser

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gas is excited by <sup>electrical</sup>~~electric~~ discharging from said  
discharging electrode and the laser light is outputted  
and for a stand-by state which differs from said in-  
operation state but in which laser light can be  
5 outputted.

Said control means may be operable to stop  
the gas circulation through said circulating means  
when said gas laser device is in said stand-by state.  
Said circulating means may include a blowing machine  
10 provided within said chamber. Said blowing machine  
may have a blowing blade rotatably supported within  
said chamber. Said laser device may comprise one of a  
noble gas halide excimer laser and <sup>an</sup>~~a~~ F<sub>2</sub> laser. Said  
noble gas halide excimer laser may comprise one of <sup>an</sup>  
15 XeCl excimer laser, <sup>a</sup>KrF excimer laser, and <sup>an</sup>ArF excimer  
laser.

In accordance with another aspect of the  
present invention, there is provided an exposure  
apparatus for exposing a substrate with the laser  
20 light, comprising: a laser light source having a  
chamber for sealingly storing a laser gas therein, a  
discharging electrode for exciting the laser gas  
through <sup>electrical</sup>~~electric~~ discharging, so that laser light is  
outputted from said chamber, and circulating means for  
25 circulating the laser gas within said chamber so that  
the laser gas passing an <sup>electrical</sup>~~electric~~ discharging region  
of said discharging electrode is circulated in said

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chamber and is returned to said <sup>electrically</sup> ~~electric~~ discharging  
region of said discharging electrode; a major assembly  
for exposing a substrate with laser light from said  
laser light source; and control means for controlling  
5 said circulating means so that said circulating means  
provides different gas circulation capacities, being  
different for an in-operation state in which the laser  
gas is excited by <sup>electrical</sup> ~~electric~~ discharging from said  
discharging electrode and the laser light is outputted  
10 and for a stand-by state which differs from said in-  
operation state but in which laser light can be  
outputted.

Said control means may be operable to stop  
the gas circulation through said circulating means  
15 when said gas laser device is in said stand-by state.  
Said circulating means may include a blowing machine  
provided within said chamber. Said blowing machine  
may have a blowing blade rotatably supported within  
said chamber. Said laser device may comprise one of a  
20 noble gas halide excimer laser and <sup>an</sup> ~~a~~ F<sub>2</sub> laser. Said  
noble gas halide excimer laser may comprise one of <sup>an</sup>  
XeCl excimer laser, <sup>a</sup> KrF excimer laser, and <sup>an</sup> ~~a~~ ArF excimer  
laser.

In accordance with a further aspect of the  
25 present invention, there is provided an exposure  
apparatus, comprising: a laser light source having (i)  
a chamber for sealingly storing a laser gas therein,

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5 (ii) a discharging electrode for exciting the laser gas through <sup>electrical</sup> ~~electric~~ discharging so that laser light is outputted from said chamber, and (iii) circulating means for circulating the laser gas within said chamber so that the laser gas passing an <sup>electrical</sup> ~~electric~~ discharging region of said discharging electrode is circulated in said chamber and is returned to said electric discharging region of said discharging electrode; a main assembly for exposing a substrate  
10 with the laser light from said laser light source; and control means for controlling said circulating means so that said circulating means provides different gas circulation capacities, being different for an exposure-operation state of said exposure apparatus in  
15 which exposure of the substrate with the laser light from said laser light source can be performed through said main assembly, and for a non-exposure-operation state of said exposure apparatus.

Said control means may be operable to  
20 increase the gas circulation capacity of said circulating means in response to <sup>the</sup> start of an exposure job in which the exposure operation is performed through said main assembly. Said control means may be operable to hold gas circulation through said  
25 circulating means stopped before <sup>the</sup> start of the exposure job. Said circulating means may include a blowing machine provided within said chamber. Said blowing

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machine may have a blowing blade rotatably supported within said chamber. Said laser light source may comprise one of a noble gas halide excimer laser and <sup>an</sup> ~~a~~ F<sub>2</sub> laser. Said noble gas halide excimer laser may 5 comprise one of <sup>an</sup> XeCl excimer laser, <sup>a</sup> KrF excimer laser, and <sup>an</sup> ArF excimer laser.

In accordance with a further aspect of the present invention, there is provided a semiconductor device manufacturing method in which a pattern is 10 lithographically transferred onto a substrate by use of any one of the exposure apparatuses as described above.

These and other objects, features and advantages of the present invention will become more 15 apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of an exposure apparatus with a gas laser device, according to an embodiment of the present invention.

Figure 2 is a longitudinal section of a 25 chamber of the gas laser device.

Figure 3 is a lateral section of the chamber of the gas laser device.



Figure 4 is a schematic view for explaining details of a rotational shaft of a blower.

Figure 5 is a flow chart for explaining operation with the gas laser device of this embodiment.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows an exposure apparatus according to an embodiment of the present invention.

10 Denoted in Figure 1 at 1 is a main assembly of a step-and-repeat or step-and-scan exposure apparatus, called a stepper. Denoted at 2 is a console with which an operator, for example, can apply a job command to a control system (not shown) in the exposure apparatus  
15 main assembly 1, for controlling the operation of the main assembly. Denoted at 3 is a laser light source having a gas laser device which is based on a noble gas halide excimer laser (called "excimer laser"), or  
20 <sup>an</sup> F<sub>2</sub> laser, for example. Examples of such <sup>an</sup> excimer laser may be <sup>an</sup> XeCl excimer laser (308 nm wavelength), <sup>an</sup> KrF excimer laser (248 nm wavelength), and <sup>an</sup> ArF excimer laser (193 nm wavelength). The following description will be made <sup>of</sup> ~~on~~ an example wherein the laser light source 3 uses a noble gas halide excimer laser.

25 The main assembly 1 of the exposure apparatus comprises a beam shaping optical system 4 for rectifying, into a desired beam shape, the sectional

shape of laser light from the laser light source 3,  
along the path of laser light (laser beam). The main  
assembly further comprises a variable ND filter 5 for  
adjusting the intensity of laser light, and an optical  
5 integrator 6 for dividing the laser light and  
superposing the divided beams one upon another for  
uniform illuminance upon the surface of a reticle 12.  
The main assembly further comprises a condenser lens 7  
for collecting laser light from the optical integrator  
10 6, and a beam splitter 8 for directing a portion of  
the laser light from the condenser lens 7 toward a  
photodetector 15. The main assembly further comprises  
a masking blade 9 disposed at a position where the  
laser light is collected by the condenser lens 7 and  
15 for regulating the range on the reticle 12 surface to  
be irradiated with the laser light. The main assembly  
further comprises an imaging lens 10 for forming an  
image of the masking blade 9 upon the reticle 12, and  
a mirror 11 for directing the path of laser light  
20 toward the optical axis direction of a projection lens  
13.

The reticle 12 can be illuminated with laser  
light projected by the laser light source 3 and passed  
through the illumination optical system having optical  
25 components such as described above. With this  
illumination, a pattern of the reticle is projected by  
the projection lens (projection optical system) 13

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onto one of different exposure shot areas on a semiconductor wafer (substrate) in a reduced scale of 1/2 to 1/10, whereby the pattern is lithographically transferred thereto. The wafer 14 can be moved two-  
5 dimensionally along a plane perpendicular to the optical axis of the projection lens 13, by means of a movable stage (not shown). As the exposure of a certain shot area on the wafer is completed, the wafer is moved to the position where the pattern of the  
10 reticle 12 is to be projected by the projection lens 13 onto a next shot area on the wafer.

Denoted at 16 is signal processing means for processing a photoelectrically converted signal, having been photoelectrically converted by the  
15 photodetector 15 and corresponding to the intensity of the laser light. Through integration of photoelectrically converted signals, a signal for controlling the exposure amount can be produced. A control signal obtained with the signal processing  
20 through the signal processing means 16 is fed back to a controller 31 of the laser light source 3. In accordance with this control signal, the controller 31 controls the subsequent light emission by the laser gas in the chamber 30 of the excimer laser 3.

25 Figure 2 is a longitudinal section of the chamber 30 of the excimer laser 3. Denoted in Figure 2 at 32 is a pair of discharging electrodes which are

connected to a high voltage source (HV), not shown.  
On the basis of the ~~electric~~<sup>electrical</sup> discharging from the  
discharging electrodes 32, the laser gas LG portion  
which is placed in the discharging region 33 between  
5 the discharging electrodes 32 is excited, whereby  
laser oscillation is executed in a known manner. The  
~~electric~~<sup>electrical</sup> discharging from the discharging electrodes  
32 is repeated periodically, such that as shown in  
Figure 3 the excimer laser 3 provides periodic outputs  
10 or oscillation of laser light 40.

The laser gas LG within the chamber 30 of the  
excimer laser 3 is circulated in the chamber 30 in  
directions (counterclockwise in Figure 2) denoted by  
arrows in the drawing, by means of a blower or  
15 circulating fan 34 of a blowing machine (circulating  
means), which is provided within the chamber 30. Thus,  
the laser gas LG passing the ~~electric~~<sup>electrical</sup> discharging  
region 33 of the discharging electrodes 32 is  
circulated in the chamber 30 and is moved back to the  
20 discharging region 33 of the electrodes 32. During  
this circulation process, the laser gas LG passes  
around a heat exchanger 35 so that it is cooled to a  
desired temperature. Within the heat exchanger 35,  
there is a flow of temperature regulating fluid such  
25 as ~~a~~ temperature controlled water or air, which is  
supplied from a temperature adjusted fluid supplying  
device (not shown) disposed outside the chamber 30.

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As shown in Figure 3, there are windows 36 and 37 before and after the <sup>electrical</sup> ~~electric~~ discharging region 33 in the chamber 30 of the excimer laser 3. The laser light produced at the discharging region 33 is amplified while being passed through the windows 36 and 37 and being reflected by an output window (half mirror) 38 (which is a laser output end) and a total reflection mirror 39. A portion of the thus amplified laser light is outputted from the output window (half mirror) 38, whereby laser light 40 is emitted as exposure light. During this process, the blower 34 is continuously rotated to circulate the laser gas LG within the chamber 30 as described above. When the laser oscillation frequency has to be increased, the number of revolutions of a blower drum 340 (Figure 4) of the blower 34 is increased to enhance the blowing power of the blower accordingly.

Around the blower drum 340, there are a number of blades (blowing fans) 345, as shown in Figure 2, mounted. With the rotation of the blower drum 240, these blades 345 operate to circulate the laser gas LG within the chamber 30. The blower drum 340 has a rotational shaft 341 which is rotatably supported by bearing means (rotational shaft supporting means) such as <sup>by</sup> ball bearing 342, for example. The lifetime of the ball bearing 342 changes with the load applied to the ball bearing 342, and the load changes with the

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rotation speed or rotation time of the blower drum  
340.

The operation of this embodiment will now be  
described with reference to the flow chart of Figure

5 5. As a voltage source for the excimer laser 3 (laser  
light source) is powered on at step S0, the sequence  
goes to <sup>a</sup>warming-up state at step S2 while the laser is  
kept in <sup>a</sup>laser-off state at step S1. In the warming-up  
state at step S2, the ~~electric~~ <sup>electrical</sup> discharging from the  
10 discharging electrodes 32 is not initiated, and also  
the blower 34 is kept stopped. The remaining  
functions are operated such that, in this state, in  
response to <sup>a</sup>start of ~~electric~~ <sup>electrical</sup> discharging from the  
discharging electrodes 32, the laser emission can be  
15 executed promptly.

In this state, if at step S3 an exposure job  
start signal, for example, is applied from the console  
2 of Figure 1 to the stepper main assembly 1 and the  
excimer laser 3, the ~~electric~~ <sup>electrical</sup> discharging from the  
20 discharging electrodes 32 of the excimer laser 3 is  
initiated. Simultaneously, the blower 34 starts its  
rotation to initiate circulation of the laser gas LG  
in the chamber 30. Thus, the excimer laser is brought  
into a laser-on state at step S4, such that laser  
25 light 40 is produced from the output window 38 of  
Figure 3. On the other hand, within the stepper main  
assembly 1, a wafer 14 introduced into the main

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assembly 1 is taken out of a wafer cassette, and it is placed on a wafer stage (not shown) which is placed at an exposure position below the projection lens 13.

Additionally, after execution of a predetermined

5 alignment operation with respect to a reticle 12, the exposure process is performed at step S5 by using the laser light 40 as exposure light. The exposure operation in the stepper main assembly 1 is repeatedly and sequentially performed until exposures of all  
10 wafers 14 set beforehand are completed.

Until the exposure operation at step S5 is completed, the blower 34 in the chamber 30 continues its rotation to continue its blowing operation.

During this period, at step S4, the laser controller 31  
15 continuously detects the rotation speed (number of revolutions) of the blower 34. If there is any error in the number of blower revolutions, the ~~electric~~ <sup>electrical</sup> discharging from the discharging electrodes 32 is discontinued. Also, the blower 34 rotation is

20 stopped. By this, the laser goes back to the warming-up state at step S2. <sup>On</sup> ~~In~~ that occasion, the laser controller 31 signals the error in the laser 3 to the console 2, such that the console 2 applies a signal to the stepper main assembly 1 to stop the job being  
25 executed, whereby the exposure operation in the stepper main assembly 1 is stopped.

If, on the other hand, any error in the

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number of revolutions is not detected, the exposure operation at step S5 is continued, and the exposure job is performed until exposures of all the wafers 14 set in the stepper main assembly 1 are completed.

5 When, at step S6, exposures of all the wafers 14 in the stepper main assembly 1 are completed and the exposure job thereto is accomplished, the stepper main assembly 1 signals the exposure job completion to the console 2. In response, the console 2 signals the  
10 exposure job completion in the main assembly 1 to the controller 31 of the laser 3. In response, the laser controller 31 stops the blower 34 rotation and, additionally, it stops the <sup>electrical</sup> ~~electric~~ discharging from the discharging electrodes 32 whereby laser  
15 oscillation from the excimer laser 3 is stopped.

In this embodiment, the blower 34 rotates only in a period in which <sup>an</sup> exposure operation is performed in the stepper main assembly 1 or in a period in which the excimer laser 3 provides laser  
20 light oscillation. On the other hand, in the stepper main assembly 1, there is a job, other than the exposure job, which necessitates oscillation of the excimer laser 3 for measurement of illuminance non-uniformness upon a reticle 12 or a wafer 14, or for  
25 temperature stabilization of the projection lens 13, for example. During a period in which such a job is executed, the blower 34 is rotated. In accordance



with this embodiment of the present invention, the  
period of term for replacement or repair of the blower  
34 or bearing means 342, that is, the lifetime of it,  
can be prolonged. Particularly, the lifetime of the  
5 blower 34 may be made longer than that of the chamber  
30.

While the invention has been described with  
reference to the structures disclosed herein, it is  
not confined to the details set forth and this  
10 application is intended to cover such modifications or  
changes as may come within the purposes of the  
improvements or the scope of the following claims.

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